

THE U.S. ARMY RESEARCH LABORATORY'S ACOUSTIC & SEISMIC DATABASE AND USER INTERFACE SOFTWARE

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ABSTRACT

The U.S. Army Research Laboratory's (ARL) acoustic and seismic data consist of various time-series signatures of battlefield ground and air targets. These signatures were collected from a number of sensor arrays placed within detection range of the targets' travel path. The growth of the collected acoustic and seismic data in the past few years has resulted in an inevitable need for a database. As the first phase of ARL's Automatic Target Recognition (ATR) Lab effort, a multiuser, client/server acoustic and seismic database and an innovative user interface software are being developed. Although not completed, the database and user-interface software are mature enough to be used by ARL researchers on a daily basis. As a parallel effort to the populating of the database, ARL has begun the second phase of the ATR Lab, which is to integrate various signal-processing algorithms to the database software. At present, most of the existing signature data have been transferred from digital tapes onto compact disks. Data from the server can be accessed and downloaded to client PCs over the local area network via the custom-written user interface software. This front-end software features data entry and query capabilities; a suite of graphic and data analysis tools to provide quick data viewing, extracting, and downloading; and the capability to seamlessly evaluate algorithms against selected data segments. The ATR Lab enables users to quickly load target signatures for evaluating the performance characteristics of target detection, tracking, and identification algorithms.

1. INTRODUCTION

The U.S. Army Research Laboratory (ARL) has maintained a significant collection of acoustic and seismic data for battlefield ground and air targets. Acoustic and seismic data are expensive to collect yet they are crucial in the development and evaluation of target tracking and identification algorithms conducted by ARL researchers. ARL's data have also been frequently requested by researchers from other government agencies, private organizations, and universities.

Data collected over the last eight years was recorded on digital audio tape (DAT). Downloading these data onto a computer is a slow and tedious process. Locating a portion of data for extraction adds to the difficulty of this process. To retrieve data, one must extract target coordinates for start and end points, correlate them with the appropriate ground truth file, and set the recorder for data downloading accordingly. There is no other systematic means to retrieve data files and correlate ground truth to signature data. Furthermore, digital tapes have a short shelf-life and need to be transferred to durable media such as a compact disk (CD) as soon as possible.

Recognizing the need for an automated centralized database to expedite data access and ease the data maintenance of a growing data collection; ARL has developed a multiuser client/server acoustic database that runs on the ARL local area network. The database is managed by Microsoft SQL Server, a high-performance and secured relational database management system. Development costs have been kept at a minimum by utilizing existing computers in the laboratory.

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This paper gives an overview of the database design and highlights the main features of the user-interface program.

2. DATABASE ARCHITECTURE OVERVIEW

The database consists of time-series target signature data files and comprehensive information about these files. Associated with each run segment is a set of data files. A typical run consists of a number of sensor arrays strategically placed along the track that a target(s) travels. A complete set of data files includes a signature data file for each of the sensor arrays, a header file (for each signature file) that contains comprehensive information about a run segment, a ground truth file, a sensor survey file, and a meteorological data file. On-line data are stored on the server's internal hard. Off-line data are stored on CDs and removable hard drives. Information used for file queries is kept in various database tables that reside on one of the server's internal hard drives.

Figure 1 depicts the hardware architecture of ARL's acoustic database. Users from client computers communicate to the server over ARL's local area network via the customized front-end software. This multi-functional software provides the capabilities to enter data into the database, query for files that meet certain conditions, view acoustic signatures in time and frequency domains, extract and download data segments from the server to a client computer. In addition, it provides the capability to seamlessly run signal-processing algorithms against selected data segments. Future version of the front-end software will support server access from clients outside of ARL over the secure network SIPRNET.

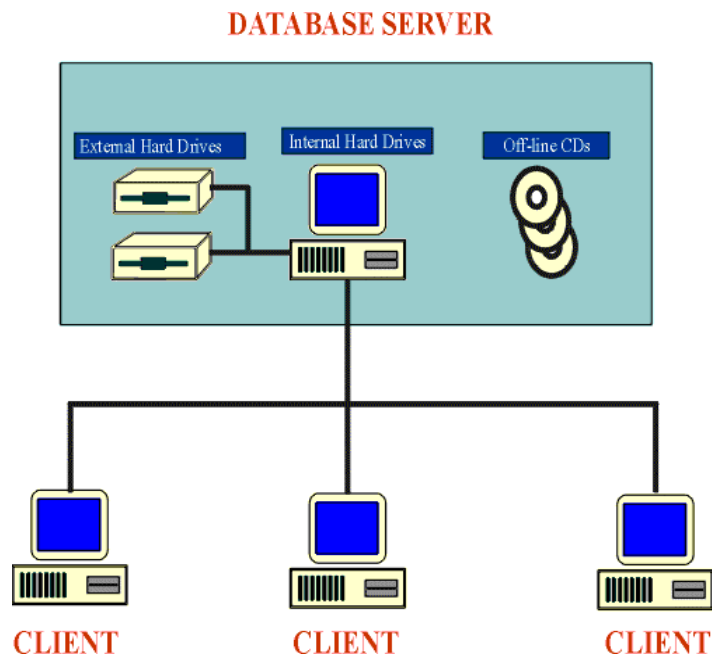


Figure 1. Database hardware architecture.

3. DATABASE SERVER

The database server consists of a 450-MHz Pentium II PC with 256 Mbytes of random access memory (RAM) and high-capacity hard drives where the database's tables, image files, and frequently accessed data are stored. As the data collection grows, additional external high-capacity hard drives will be added to the server to expand storage capability. Off-line data are stored on CDs, thus allowing unlimited storage capability.

The server runs under Windows NT Server 4.0 operating system and is dedicated to the tasks of running the database engine Microsoft SQL Server 6.5. Users from remote client computers can simultaneously access the database on the server. A Windows NT Server and an SQL Server user access license are required for each database connection. SQL Server is capable of handling hundreds of concurrent users without compromising its performance.

Signature data files and associated information are centrally stored on the server. The capability to modify the database requires access to an administrator's login identification (ID) and password. The administrator is responsible for designing the database structure, setting users' access permissions, and the maintenance and backup of the data.

4. CLIENTS

A client consists of any PC that is running Windows NT, Windows 95, or Windows 98. A login ID and password are required for a client to connect to the server and query, view, or download data files. SQL Server is powerful and is dedicated solely to managing data. It is not equipped with an easy-to-use interface. To enable better communication between the user and the server, ARL has developed an innovative user-friendly front-end program. Residing on each client PC, this front-end program combines point-and-click operations, text, graphics, and audio to provide the user with an effortless means to interface with the server. The database design takes advantage of the client/server architecture by having both server and client share the workload, resulting in a combination of processing power at both ends of the system.

At a minimum, the server and client PCs should be equipped with the software shown in table 1.

Table 1. Software requirements for acoustic and seismic database

Server	Client
Operating system:	Operating system:
Windows NT Server	Windows 95, 98, or NT
Database management system:	ARL's User interface software
Microsoft SQL Server	Microsoft SQL Server ODBC driver
	MATLAB (optional)
SQL = structured query language	ODBC = open database connectivity

5. DATABASE/ATR USER-INTERFACE SOFTWARE

Microsoft Visual Basic, Professional Edition, version 6.0, was selected as the development language for the database/ATR user-interface software because it supports the development of commercial-quality Windows graphical user interface (GUI) applications. Other factors that support the choice of Visual Basic are its low cost (applications are distributed with no runtime fees), vendor stability, and extensive third-party add-on products.

The user-interface software consists of three separate modules: data entry, file query, and view/download/ATR tools. To execute the program, the user needs a login ID and password (user's or administrator's). The data entry module is available to all users for viewing, but database modifications can be performed only by users with administrator privileges.

5.1 DATA ENTRY MODULE

The administrator can access all database tables from the data entry module. Depending on the information that they contain, the tables are divided into one of four categories: file, target, sensor, and data collection. Figure 2 shows the Data Entry window, which displays 1 of the 16 records from the table Ground_Targets (this table contains information on ground targets). The table has been selected from the list of tables in the Targets folder. The number of records in the table is indicated on the status bar at the bottom of the screen. The four buttons—First, Prev, Next, and Last—enable maneuvering between records in the table. Records in a table can be sorted by any field such as Target_ID, Target, Class, etc. The edit buttons allow the addition, modification, and deletion of records in a table. The search utility is used to search for a record by any field. The Print Record button generates a hard copy of the displayed record. The target picture on the screen can be enlarged by placing the mouse's arrow on the picture and clicking the mouse's left button.

The Data Entry window only allows viewing and editing one table record at a time. However, the administrator may need to view multiple records and make bulk changes. This capability is provided in the SQL Command window where the administrator writes an SQL command to be passed to the server to query for results or make changes to several records simultaneously. Figure 3 is a sample window that displays returned information from the server in response to the SQL command SELECT.

The screenshot shows the 'Data Entry' application window with the 'Targets' tab selected. The 'Select table:' dropdown is set to 'Ground_Targets'. The record for Target_ID 4 is displayed with the following details:

Field	Value
Target_ID	4
Target	M548 Combat Support Equipment
Class	light tracked
Country	USA
Weight (kg)	7435
Length (m)	5.892
Width (m)	2.686
Height (m)	2.673
Engine	GMC 6-cylinder liquid cooled diesel 21C hp @ 2600 rpm
Transmission	A torque converter gives 1 forward and 2 reverse speeds
Max Speed (mph)	0.4
Crew	2
Picture	m540_1.gif;m540_2.gif
Signature	y

On the right side of the window, there are buttons for 'Move record' (First, Prev, Next, Last), 'Sort by' (Target_ID, Sort), 'Edit' (Add, Add/C, Modify, Update, Clear, Delete), and 'Search by' (Target, Enter text, M548, Go). A 'Print Record' button is also present. At the bottom right, a small image of the M548 vehicle is shown with the label 'M548'. The status bar at the bottom indicates '# Records: 16'.

Figure 2. Data Entry ground target window.

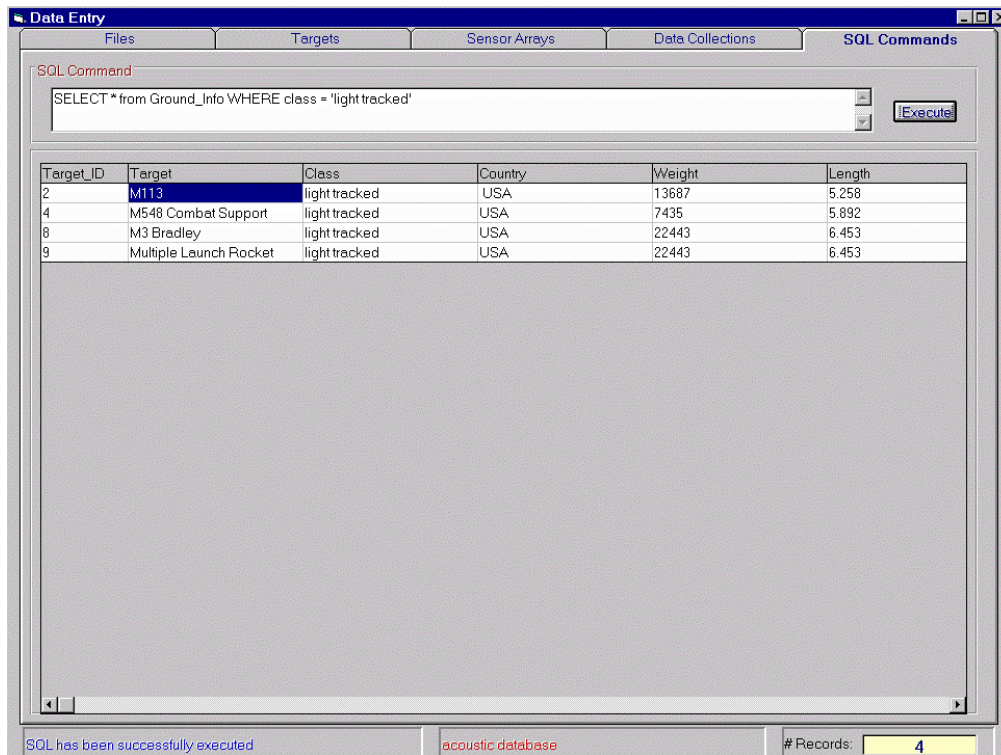


Figure 3. Data Entry SQL command window.

5.2 QUERY MODULE

The query module is where the user searches for data files that satisfy selected criteria in four categories: target, sensor, data collection, and meteorological condition. This easy-to-use user interface requires only point-and-click actions and minimum typing, as depicted in figures 4 and 5. Figure 4 shows the Target Select window and figure 5 shows the Sensor Array Select window. In both figures, the list boxes are populated with data that are in the database at the time the database is opened. As entries are added to or deleted from the database, the contents of the list boxes change accordingly when the database is reopened.

To populate the Targets list boxes, the user must (1) select one or more entries of signature type, target category, country, and class from the associated menus (fig. 4). Targets with or without signature data in the database are listed separately. Double-clicking on a target name in either list box will open up a Target Information window; for example, figure 6 shows such a window with information about an HMMWV.

The two separate list boxes in the Target Select window (fig. 4) allow the user to browse target information, yet they prevent the user from making queries on targets without signature data. Thus this feature saves time that would have been spent searching for nonexistent files.

For convenience, the user has the option of choosing the unit for speed in either miles per hour (mph) or kilometers per hour (kph) and the unit for temperatures in either Celsius (°C) or Fahrenheit (°F). However, speeds and temperatures are entered in the database in kph and °C.

If the user needs to repeat a query at a later time, he has the option of saving the query setting in a file with the Save Query button (see fig. 4). Clicking on the Load Query button will load the saved query into the query windows where it is ready to be used again or modified, if necessary. To send the query to the server and receive the resulting list of files, the user can click on the Run Query button.

Data Query

TARGETS SENSORS DATA COLLECTIONS MET CONDITIONS

Target type

Signature: continuous

Category: air
ground

Country: (ALL)
Russia
USA

Class: (ALL)
heavy/medium tracked
heavy/medium wheeled
light tracked
light wheeled

Targets with signatures:

(ALL)
ambience
M60 Main Battle Tank
M113
M548 Combat Support Equipment
2.5-Ton Truck
HMMWV
M3 Bradley
Multiple Launch Rocket System
M1A1

Targets without signatures:

5-Ton Cargo Truck

Number of targets

(ALL)
1
2
3

Speed (mph)

☒ ALL
☐ Above
☐ Between
☐ Below

Background

(ALL)
ambience

Terrain

(ALL)
asphalt
asphalt/gravel
grass
gravel


 **Load Query** **Save Query** **Run Query**

Figure 4. Target Select window.

Data Query

TARGETS SENSORS DATA COLLECTIONS MET CONDITIONS

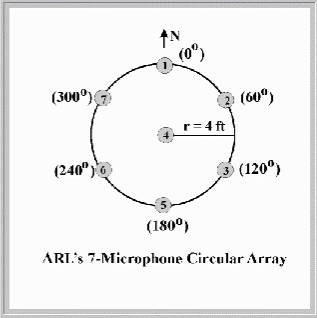
Sensor arrays

Domain: (ALL)
acoustic
acoustic/seismic

Array config: (ALL)
circular
triangular

Array size: (ALL)
7
8

Array name: (ALL)
ARL 7-Acoustic Circular Array 1
ARDEC 7-Acoustic Circular Array



ARI's 7-Microphone Circular Array

Load Query **Save Query** **Run Query**

Figure 5. Sensor Array Select window.



Figure 6. Target Information window.

Figure 7 is a sample window that displays the available files returned from the server. The list boxes Online Signature Files Found and Offline Signature Files Found contain online and offline signature filenames that meet the query's conditions. The Select Media list box lists labels of the media where offline files are stored. The user can choose to display offline files for select media.

The user can obtain general information about any file by double clicking on the filename in any list box. This action invokes the Signature File Information window shown in figure 8. Online and/or offline files that are of interest to the user can be selected and moved to the right list boxes to be saved in a text file for future reference. Files can be moved back and forth between right and left list boxes. Selecting the Save button on the Query window (see fig. 7) will write the selected online and offline files into a text file.

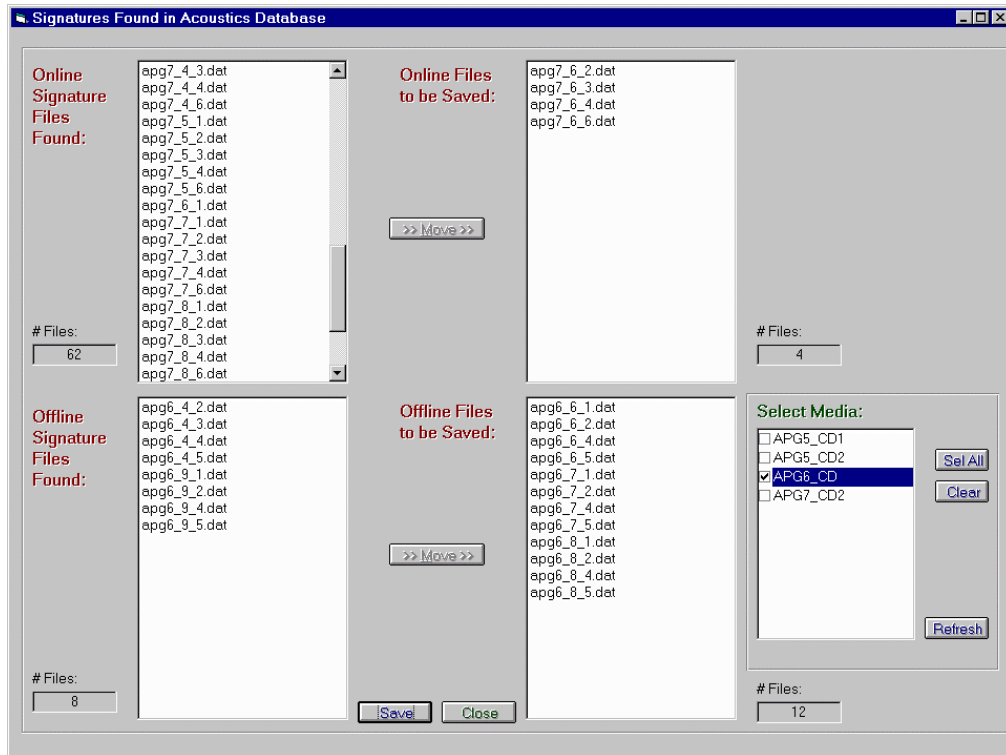


Figure 7. Query result window.

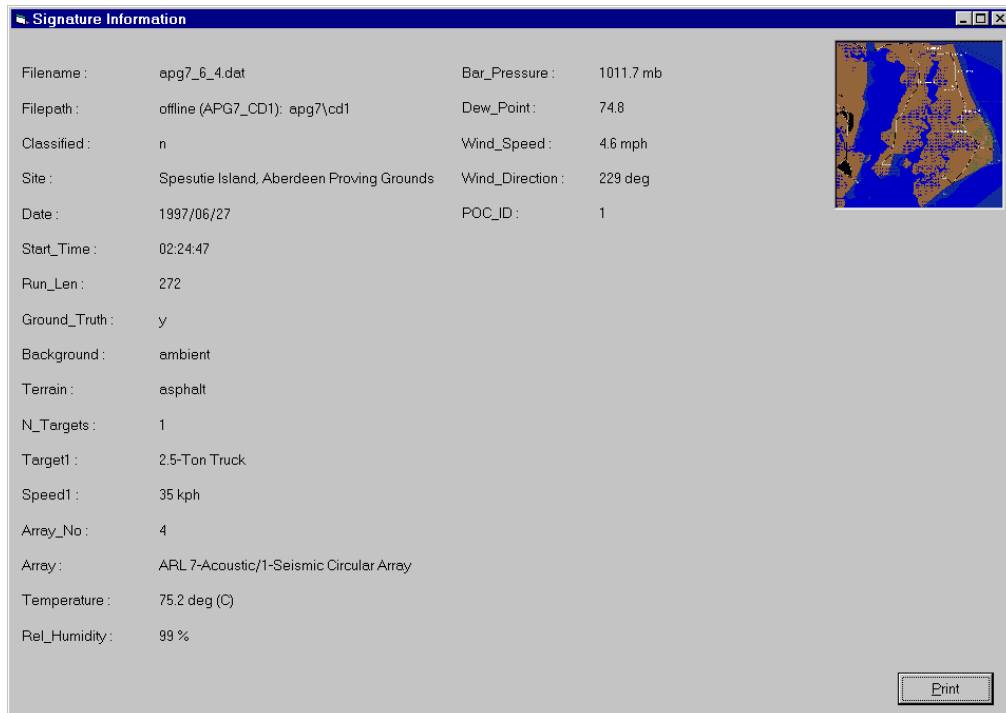


Figure 8. Signature Information window.

5.3 TOOLS MODULE: DATA VIEWING AND DOWNLOADING UTILITIES

The tools module is a suite of tools that enables the user to select the target's start and end positions on the track. The acoustic and seismic signal for this selected segment of the run can be plotted in time and frequency domains and downloaded from the server to the client. The user is provided with a mechanism to integrate signal-processing algorithms to the tools module and evaluate them against run segments of selected lengths from the module.

5.3.1 Plot Descriptions

The tools module displays four types of plots: ground truth, time series signature, power spectral density, and spectrogram.

Ground Truth Plot: A signature file is opened via the Open List or Open File button (see fig. 9). If target ground truth and sensor survey files exist for the open file, the ground truth plot is generated automatically. The ground truth plot in figure 9 displays six sensors along the target track. The filename `apg8_45_1.dat` on the status bar indicates that the data are for run number 45 and array number 1. Array number 1 (of the open file) is highlighted in a different color from that of the other sensors.

Clicking on the Play button on the left-hand side of the ground truth plot will plot the targets as they move along the track from the beginning of the run until the end. The From and To sliders provide the option to manually select the start and end positions of targets. In figure 9, the sliders have been moved to select the two targets' start positions at 142 s and end positions at 187 s from the beginning of the run. The two targets' start and end positions are indicated by the four dots, labeled 1s and 1e for target 1, and 2s and 2e for target 2. Each target is plotted in a different color. Double-clicking the left or right mouse button with the mouse pointer on the plotted area will cycle the label through different types that show the following: target number with start and end indication (1s, 1e, 2s, 2e), distance from target to highlighted sensor array, target universal transverse mercator (UTM) coordinates, line of bearing, and labels off.

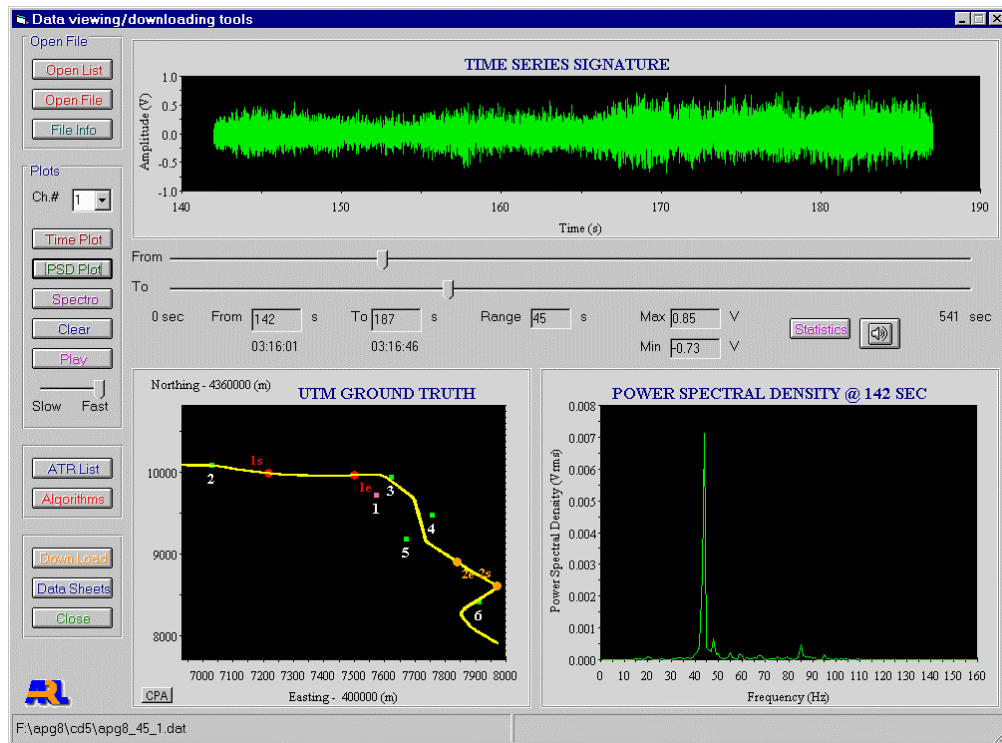


Figure 9. Tools module main window.

Time Series Plot: The time series signature plot for the select channel is generated when clicking on the Time Plot button. The plot in figure 9 is for the selected time range from 142 to 187 s, a 45-s time period. A different time range can be selected with the sliders and the time series signature can be replotted using the Time Plot button.

Power Spectral Density Plot: The Power Spectral Density plot displays the frequency contents of the signature data at the second selected by the To slider. By moving the slider to another time point and clicking on the PSD Plot button, the power spectral density is replotted at that second.

Spectrogram: The spectrogram for the selected time frame is plotted with the Spectro button, (see fig. 9) and an example of this window is shown in figure 10. The three dimensional (3-D) spectrogram can be rotated 360° degrees to obtain the best viewing angle.

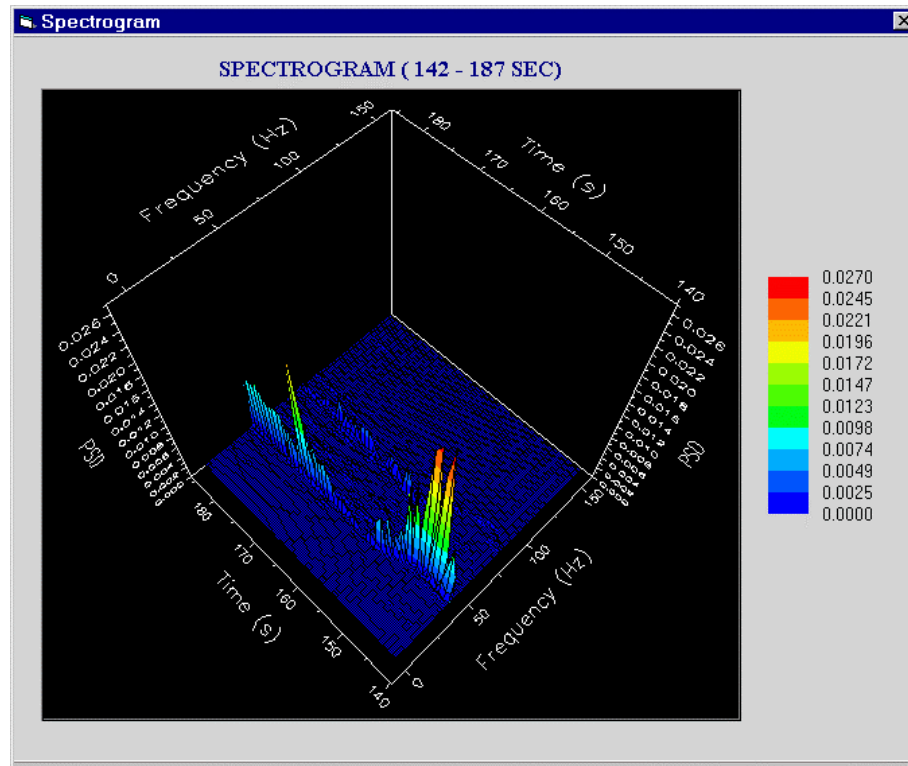


Figure 10. Spectrogram of a selected data segment.

5.3.2 File Header Viewer

Header information for each signature file is stored in a binary header file. The advantage of having the header file separate from the data file is that this provides the user with the capability to easily modify the header information due to its size (< 1 KB) as compared with having it combined with the data file (tens of MB). Some database parameters (target type, sensor array type, test site, etc.) use ID numbers instead of actual names for ease in making modifications and also for security purposes.

The information stored in the header file can be viewed by clicking on the File Info button (see fig. 9). This will open the Header Information window. Figure 11 shows this window, which displays sensor/calibration information for the open file (from a field test). The header information is organized in different folders for ease of viewing.

File header information

Targets | **Sensors/Calibration** | Met Condition | File | General

Array # Array ID Array size ☒ Anti-aliasing filter

Calibrator
ID: 1
Serial number: 1 607 120
SPL Vpp: 93.8 dB
Frequency: 1 kHz

Sensor 1 Type: microphone ID: 1 Front-end gain: 100 Vpp: 3.451 V	Sensor 2 Type: microphone ID: 1 Front-end gain: 100 Vpp: 4.518 V	Sensor 3 Type: microphone ID: 1 Front-end gain: 100 Vpp: 3.951 V	Sensor 4 Type: microphone ID: 1 Front-end gain: 100 Vpp: 3.451 V
Sensor 5 Type: microphone ID: 1 Front-end gain: 100 Vpp: 4.298 V	Sensor 6 Type: microphone ID: 1 Front-end gain: 100 Vpp: 4.518 V	Sensor 7 Type: microphone ID: 1 Front-end gain: 100 Vpp: 4.173 V	Sensor 8 Type: geophone, z ID: 2

ARL 7-Acoustic/1-Seismic Circular Array

Print to Printer Print to File

Figure 11. File Header Information window.

5.3.3 All-Channel Statistics

To quickly view the statistics for all microphone/geophone channels, click on the Statistics button (see fig. 9). From the statistics information, a bad channel can be identified quickly. Figure 12 shows an example of the statistics for the selected time range.

Statistics of all channels for the selected time range

Channel No	Maximum (V)	Minimum (V)	Mean (V)	Standard deviation (V)
<input type="text" value="1"/>	<input type="text" value="5.00"/>	<input type="text" value="-5.00"/>	<input type="text" value="0.01"/>	<input type="text" value="1.11"/>
<input type="text" value="2"/>	<input type="text" value="4.99"/>	<input type="text" value="-5.00"/>	<input type="text" value="0.01"/>	<input type="text" value="1.00"/>
<input type="text" value="3"/>	<input type="text" value="5.00"/>	<input type="text" value="-5.00"/>	<input type="text" value="0.00"/>	<input type="text" value="1.33"/>
<input type="text" value="4"/>	<input type="text" value="5.00"/>	<input type="text" value="-4.99"/>	<input type="text" value="0.01"/>	<input type="text" value="1.00"/>
<input type="text" value="5"/>	<input type="text" value="4.99"/>	<input type="text" value="-5.00"/>	<input type="text" value="0.00"/>	<input type="text" value="1.27"/>
<input type="text" value="6"/>	<input type="text" value="5.00"/>	<input type="text" value="-5.00"/>	<input type="text" value="0.00"/>	<input type="text" value="1.20"/>
<input type="text" value="7"/>	<input type="text" value="5.00"/>	<input type="text" value="-5.00"/>	<input type="text" value="0.01"/>	<input type="text" value="1.18"/>

Figure 12. Signature statistics.

5.3.4 Audio Playback

The plotted time series signature can be heard from the PC speakers by clicking on the button with the speaker icon (fig. 9). Due to the low-frequency contents of the targets' signature, a set of quality speakers with an appropriate frequency response is needed for generating high-fidelity sounds.

5.3.5 Data Sheets

For convenience, data sheets for microphones, geophones, and calibrators are included. A sample data sheet is shown in figure 13.

The screenshot shows a Windows-style window titled "Data sheet". It contains several sections:

- Directory of data sheets:** A text box containing the path "\\dbserver\acoustic atr\datasheets".
- Instrument type:** Three radio buttons: "Microphone" (selected), "Geophone", and "Calibrator".
- Instrument ID:** A label "Enter ID:" followed by a text box containing "1" and a green "Go" button.
- Parameters:** A list of fields with corresponding text boxes:
 - Manufacturer: Knowles
 - Model: BL 1994
 - Type: Random Incident
 - Frequency response: 40 - 40000 Hz
 - Polarization Voltage: 0.9 - 10 Vdc
 - Sensitivity: -69dB Re 1.0V/microbar @ 1kHz
 - Operating Humidity Range: (empty)
 - Operating Temp Range: (empty)
 - Max. SPL: (empty)
 - Capacitance: (empty)
 - Dynamic Range: (empty)
 - Lower Limiting Frequency: (empty)
 - Diameter: 12.7 mm
 - Height: 25.4 mm

Figure 13. Microphone data sheet.

5.4 TOOLS MODULE: ATR ALGORITHMS

Included in the tools module is the capability to attach a signal-processing algorithm (target detection, tracking, identification, etc.) to one of the many available buttons in the ATR Algorithms Window and create lists of data segments to evaluate these algorithms against. The capability to quickly load data and run algorithms seamlessly within the same application greatly expedites the algorithm evaluation effort.

5.4.1 Data Segment List

Once data segments are selected from the Tools main window, the user may want save them to an ATR list for algorithm evaluation. Figure 14 is an example of an ATR list. Each data segment is indicated by the start time (the number of seconds from the start of a run) and duration in seconds. Sensors (or

channels) that are not to be included in the algorithms are marked for omit (such as sensor 5 in line 3). A saved list can be reloaded and modified at a later time.

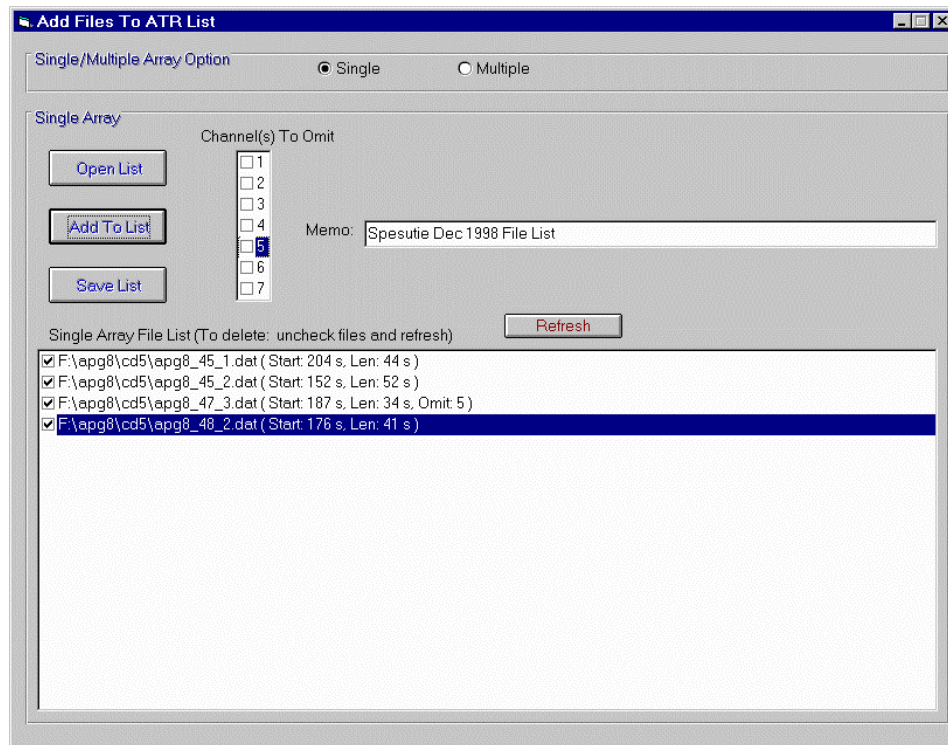


Figure 14. ATR List.

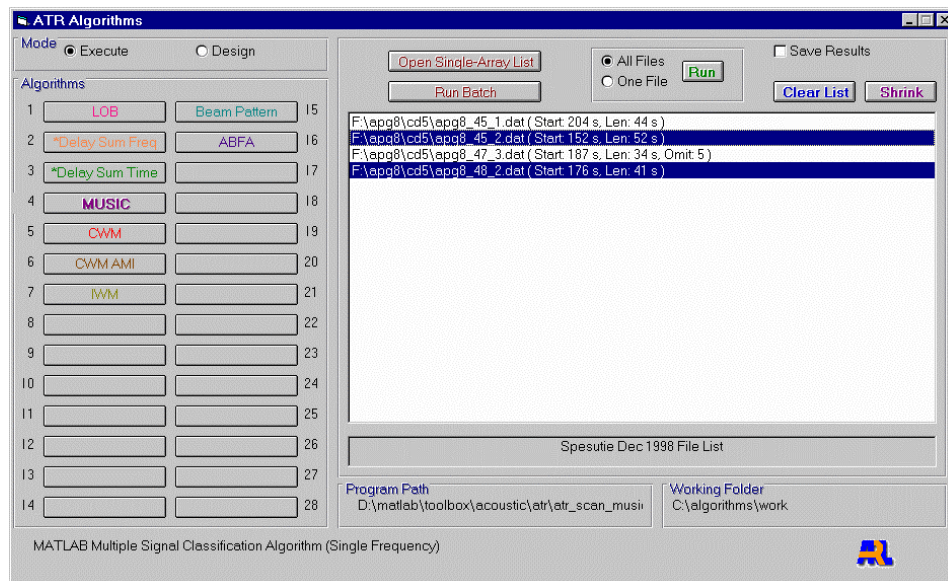


Figure 15. ATR Algorithms window.

5.4.2 Algorithm Attachment

To establish communication between the algorithm and the ATR programs, the algorithm program has to adhere to certain predefined protocols. To attach an algorithm (in a MATLAB M file or executable file) to one of the blank buttons in the ATR Algorithms window (shown in Fig. 15) is straightforward. The user selects the Design option in the ATR Algorithms window and clicks on a blank button to bring up the Attach Algorithm to Button window. Figure 16 shows this window, where the user selects the path to the executable file and working directory to store results. The user then types in the button's caption and selects the caption's font color. Clicking the Done button finishes the attachment of the algorithm to the selected button.

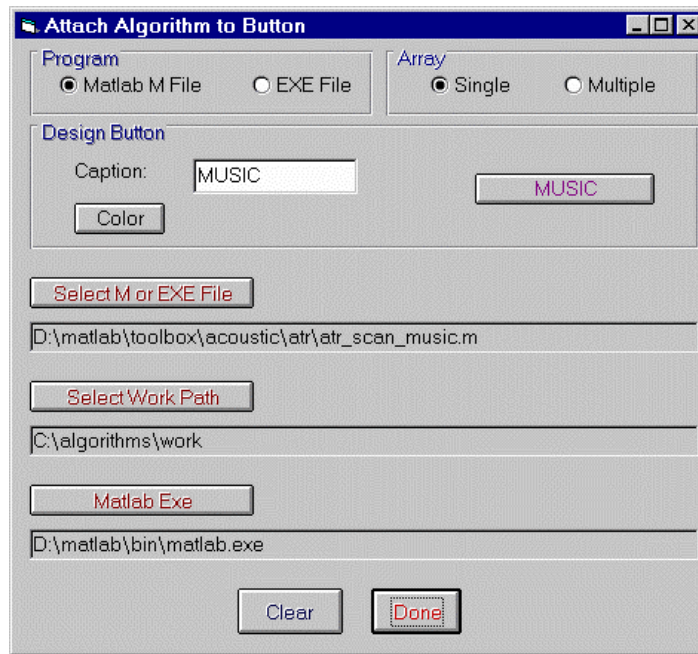


Figure 16. Algorithm Design window.

5.4.3 Algorithm Deployment

To deploy an algorithm against a list of run segments is just a few mouse clicks away. First, the user selects an algorithm from the many available buttons and opens the single array list containing the selected data segments. Multiple data segments can be selected from the displayed list. The user has the option to run the algorithm against one data segment automatically after another. The other option allows the program to pause after processing each data segment to allow the user time to view the output plots. The user continues with the next data segment when clicking the Run button.

The user also has the option to deploy multiple algorithms against multiple lists of data segments in the batch-processing mode. Figure 17 illustrates a user-created processing batch, where two delay sum algorithms are evaluated against the same list of data segments. Each algorithm has its own ATR lists. Automatic algorithm deployment allows the user to create a large batch and have it processed unattended overnight.

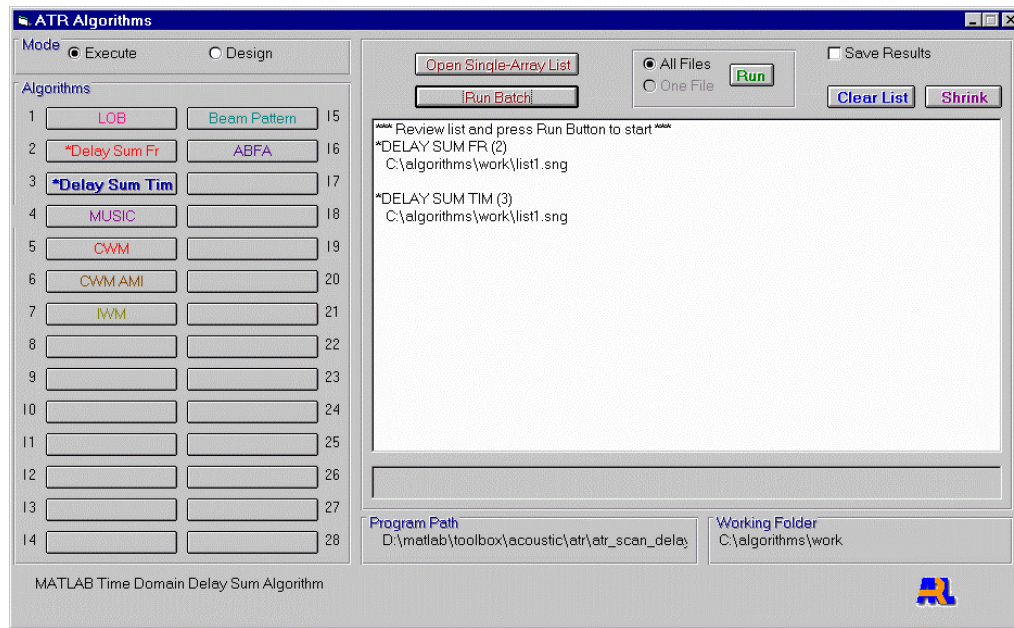


Figure 17. Deployment of algorithms in batch mode.

6. CONCLUSION

The acoustic and seismic database is an integral component of the Acoustic Automatic Target Recognition (ATR) Lab, which is an ambitious project currently under development at ARL. The emphasis of the project is to archive data for all the various field experiments into the database and develop ATR tools to process and evaluate these data.

ARL is continuing to populate the database with air and ground target data and will expand the database to include transient signatures. Although the current user-interface software is fully functional and has been used on a daily basis, there are plans for making enhancements to it. Software development will include further integration of MATLAB and/or C algorithms for target detection, direction finding, classification, identification, and data fusion into the program. There is also a plan to expand data access to clients outside ARL.